5933

Control of Enzymatic Browning in Pre-peeled Potatoes by Surface Digestion

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ABSTRACT

Feasibility of lye digestion to remove surface tissues from peeled potatoes prior to treatment with browning inhibitors to extend shelf-life was investigated. Russet and round-white potatoes were digested in 14–20% NaOH at 35–55°C for 1–13 min. After removal of digested tissue, tubers were treated with ascorbic acid-based browning inhibitor. Browning was measured by tristimulus colorimetry. Digestion extended shelf-life of high pressure steam- and abrasion-peeled potatoes to 13–15 days at 4°C, compared to 3–11 days for undigested controls. Digestion resulted in weight losses of 12–26%, depending on treatment conditions. Lye digestion in conjunction with conventional browning inhibitors represents a viable alternative to sulfiting pre-peeled potatoes.

Key Words: potatoes, enzymes, browning, lye digestion

INTRODUCTION

ENZYMATIC BROWNING in pre-peeled potatoes is a major problem for processors. Pre-peeled potatoes have been treated with sulfites to control browning (Feinberg et al., 1987). However, evidence that exposure to sulfites may cause adverse health effects has practically eliminated this practice (Taylor et al., 1986). A regulation excluding sulfites to control enzymatic browning in fresh potatoes was promulgated by the U.S. Food and Drug Administration (Anon., 1990a) but is not in effect because of legal challenges (Anon., 1990b). Available alternatives to sulfites do not meet shelf-life requirements for this product without special packaging or cover solutions (Langdon, 1987; O'Beirne and Ballantyne, 1987; Santerre et al., 1991). Previously, we reported that experimental browning inhibitor formulations containing ascorbic acid-2-phosphates were more effective than ascorbic acid (AA)-based formulations (Sapers and Miller, 1992). The shelf-life of pre-peeled potatoes, treated with experimental formulations, still do not meet industry requirements, however, and the AA-2-phosphates are not approved for food use.

Abrasion- and steam-peeled tubers undergo browning to a greater extent than tubers peeled with a sharp knife, presumably due to more extensive tissue damage (Sapers et al., 1989). Low pressure steam and high temperature lye peeling may produce a cooked layer at the tuber surface in which partially denatured, heat-activated enzyme systems could cause intense darkening. Such discolorations may be controlled only if peeled potatoes are treated with stronger than normal solutions of SO_2 (Harrington et al., 1956; Smith and Huxsoll, 1987). Since severity of browning in pre-peeled potatoes appears related to surface damage during peeling, an alternative approach to use of AA-2-phosphates might be removal of damaged tissue by digestion prior to application of a conventional browning inhibitor. Harrington (1957) patented a 2-stage lye peeling process in which the second stage was a low temperature lye digestion treatment to remove the layer of cooked tissue produced by high temperature lye peeling from the first stage. Following peeling and lye treatment, the potatoes were sulfited. By that process, peeled potatoes of "exceptional keeping quality" were produced. Our objective was to determine whether such digestion process might be applicable to potatoes peeled by abrasion or steam as well as by lye to produce a "clean" surface, amenable to treatment with a conventional ascorbic acid-based browning inhibitor formulation, so that 14-day storage life might result.

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MATERIALS & METHODS

RUSSET and round-white potatoes were obtained from local food stores and held at 4°C or 20°C until needed. Tubers were abrasion peeled with a Toledo Vegetable Peeler (Model A1-15; Toledo Scale Co., Toledo, OH); high pressure steam peeled at 1400 kPa for 15.5 sec, followed by cooling and washing in a high pressure water spray; or lye peeled for 3 min in 17% NaOH at 88°C, followed by cooling in cold water and peel removal with a brush. Weight losses for abrasion, lye and high pressure steam peeling were 38.8, 16.0, and 6.8, respectively, for Russet and 29.4, 15.8, and 4.6, respectively for round-white potatoes. Peeled tubers were briefly stored in a holding solution containing 2% sodium acid pyrophosphate (SAPP) and 0.25% NaCl prior to further treatment.

Peeled tubers were digested by immersion in 14–20% NaOH for 1–13 min at 20°–55°C. In some trials, 0.1 or 0.2% Tween 80 or Triton X-100 (Sigma Chemical Co., St. Louis, MO) or 0.2 or 0.4% sodium dodecyl sulfate (SDS; Sigma) or Aerosol OT (dioctyl sodium sulfosuccinate; American Cyanamid Co.) were dispersed in the digestion solution with a Polytron homogenizer (Brinkmann Instruments Co., Westbury, NY). Treated tubers were drained, placed in cold water, brushed to remove digested tissue, washed, and briefly stored in holding solution until treated with browning inhibitors. In some trials, weight losses due to peeling and digestion were measured in duplicate.

Table 1—Weight loss during lye digestion of peeled potatoes

Method of peeling	Digestion conditions		Russet		Round-White	
	NaOH (%)	Temp (°C)	Digestion time (Min)	Weight loss (%)	Digestion time (Min)	Weight loss (%)
Lye	17	49	2	14.8±1.0	6	20.5±0.8
			4	18.1±0.2	8	22.8±0.8
			8	24.4±1.4	10	23.6±1.4
Abrasion	17	49	2	14.2±0.6	6	20.6±0.3
			4	16.4±0.2	8	21.8±0.6
			8	23.4±0.3	10	24.0±0.8
High pressure steam	17	49	2	15.5±0.1	6	17.9±1.3
			4	19.0±1.6	8	19.8±0.2
			8	26.3±1.7	10	22.5±1.1
		35	–	–	7	16.2±1.0
			–	–	10	19.6±0.5
			–	–	13	23.1±1.0
	14	49	–	–	2	11.7±1.1
		55	–	–	2	13.6±2.0
	17	49	2	14.6±1.3	2	12.5±1.1
		55	2	15.6±0.9	2	12.8±1.4
	20	49	2	15.7±1.5	2	12.8±1.1
		55	2	14.4±0.3	2	–
	17	49	4	17.6±0.5	4	14.4±0.4
	17 Tween 80[a]	49	4	17.8±0.6	4	14.7±0.4

[a] 0.2% Tween 80 in 17% NaOH.

Table 2—Effect of digestion with NaOH and Tween 80 on browning in high pressure steam-peeled potatoes during storage at 4°C

Potato	Tuber storage (°C)	Digestion treatment[a]	Browning inhibitor[b]	Days 3	6	10	13	15
Russet	20	None	Conv.	2[d]	2[d]	−9[d]	−29[d]	−11[d]
		NaOH	Conv.	90[c]	82[c]	69[c]	51[c]	52[c]
		NaOH + Tween 80	Conv.	93[c]	90[c]	79[c]	67[c]	59[c]
		NaOH + Tween 80	Exp.	93[c]	96[c]	92[c]	67[c]	62[c]
	4	None	Conv.	89[c]	51[d]	3[d]	−4[c]	−17[d]
		NaOH	Conv.	95[c]	100[c]	88[c]	74[c]	63[c]
		NaOH + Tween 80	Conv.	94[c]	95[c]	91[c]	83[c]	80[c]
		NaOH + Tween 80	Exp.	89[c]	94[c]	102[c]	88[c]	75[c]
Round-White	20	None	Conv.	86[c]	20[d]	6[d]	6[d]	4[d]
		NaOH	Conv.	92[c]	89[c]	80[c]	73[c]	68[c]
		NaOH + Tween 80	Conv.	94[c]	92[c]	86[c]	81[c]	76[c]
		NaOH + Tween 80	Exp.	92[c]	94[c]	88[c]	62[c]	40[cd]
	4	None	Conv.	130[c]	38[d]	−2[e]	2[d]	3[c]
		NaOH	Conv.	100[d]	94[c]	72[cd]	53[c]	39[c]
		NaOH + Tween 80	Conv.	94[d]	72[cd]	53[cd]	48[c]	31[c]
		NaOH + Tween 80	Exp.	96[d]	101[c]	93[c]	68[c]	44[c]

[a] 4 min at 49°C in 17% NaOH or 17% NaOH + 0.2% Tween 80.
[b] Conv. = conventional; Exp. = Experimental. See text for formulation composition. Dipping time: 5 min.
[c-e] Mean of three β replicates; means within columns for each potato type and storage temperature, followed by different superscripts, are significantly different at $P < 0.05$ by the Bonferroni LSD test.

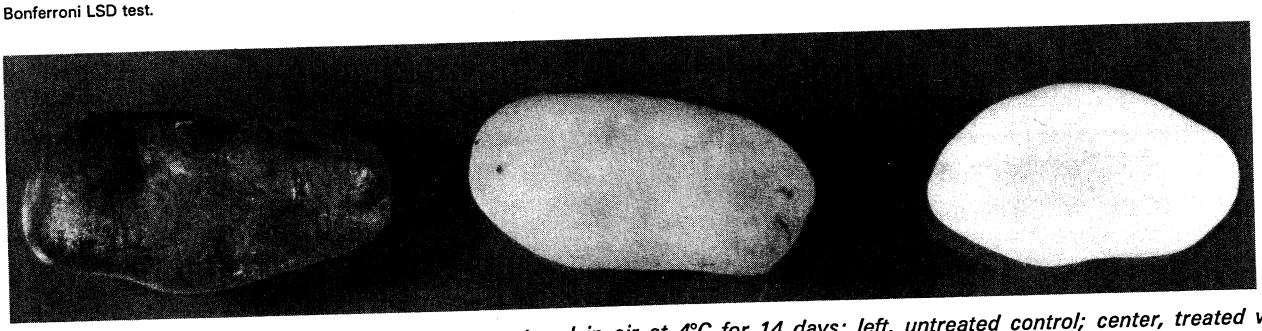

Fig. 1—High pressure steam-peeled Russet potatoes stored in air at 4°C for 14 days: left, untreated control; center, treated with conventional browning inhibitor applied after peeling; right, digested with 17% NaOH for 4 min at 49°C after peeling, then treated with conventional browning inhibitor formulation.

Whole peeled tubers, or plugs cut from peeled tubers with an electric cork borer, as described previously (Sapers and Miller, 1992), were immersed for 5 min in a "conventional" browning inhibitor solution comprising 4% AA, 1% citric acid (CA), 1% SAPP and 0.2% $CaCl_2$. Alternatively, an experimental formulation containing 2.5% AA, 1% CA, 1% SAPP, 0.2% $CaCl_2$ 1.6% ascorbic acid-2-phosphate (Mg salt), and 1.5% ascorbic acid-2-triphosphate (Na salt), adjusted to pH 2 with H_3PO_4, was substituted for the conventional formulation. Treated tubers were drained, packaged in plastic bags, and stored at 4°C for visual observation. Treated plugs were drained, blotted on absorbent tissue to remove excess solution from the circumferential surface, and stored in covered crystallizing dishes to minimize dehydration.

Discoloration at the peeled surface of plugs from control (untreated) and treated tubers was measured with a Gardner XL-23 tristimulus colorimeter (Byk-Gardner, Silver Spring, MD), as described previously (Sapers and Miller, 1992). Percent inhibition values were calculated from changes in L- and a-values (ΔL and Δa), indicative of darkening and color change, respectively, as follows:

$$\%\ \text{Inhibition (L-value) at time t} = \frac{\Delta L\ control - \Delta L\ treatment}{\Delta L\ control} \times 100$$

where $\Delta L = L_t - L_{initial}$. Percent inhibition values approaching 100% indicate that a treatment is highly effective in controlling browning while values of 50–60% represent the limit of acceptability for potatoes. Measurements were made on duplicate plugs obtained from each of three tubers/treatment. Responses were examined by the Bonferroni LSD mean separation test (Miller, 1981).

RESULT & DISCUSSION

Removal of digested tissue

Digestion of lye-or high pressure steam-peeled tubers with 17% NaOH produced a yellow gelatinous tissue layer that could be removed by brushing. We observed that the ease of removal of this layer varied with digestion temperature and time. When digestion was carried out at 30°C or less, brushing was ineffective in removing the digested tissue, even when digestion times as long as 13 min were used. The peel could readily be removed by brushing when digestion was carried out at 35°C for 7–8 min or longer or at 49°C or 55°C for 2 min or longer. Digested tissue could be removed less readily following digestion at 55°C for 1 min.

Weight losses during digestion

While some weight losses are inherent in removal of tissue damaged during peeling, such losses should not be excessive for the digestion treatments to be commercially useful. Weight losses, which ranged from 11.7% to 26.3%, (Table 1) increased with increasing digestion time at each temperature and could be minimized by high temperature-short time digestion. Shorter digestion times were required with Russet than with round-white tubers. At the same digestion time, weight losses were greater with Russet than with round-white. Losses were largely independent of NaOH concentration and addition of detergents to the digestion solution. The minimum loss corresponded reasonably well to the calculated loss based on the volume of a spherical shell, with the thickness of the cooked layer after steam or lye peeling, as a percentage of volume of a sphere with the diameter equal to that of a potato.

Browning of treated tubers

Preliminary experiments indicated digestion of lye-peeled potatoes with 17% NaOH, as described by Harrington (1957), followed by dipping in a browning inhibitor solution, could

Table 3—Effect of digestion with NaOH and anionic detergents on browning in abrasion-peeled Russet potatoes during storage at 4°C

Digestion treatment[a,b]	Digestion time (Min)	Percent inhibitor (a-value) Days 4	6	11	13	15
None	0	90[c]	71[d]	58[d]	52[d]	44[d]
NaOH	4	95[c]	87[c]	84[c]	77[cd]	67[cd]
NaOH	6	94[c]	82[cd]	80[cd]	74[cd]	65[cd]
NaOH + 0.2% SDS	4	91[c]	86[c]	80[cd]	74[cd]	66[cd]
NaOH + 0.2% AOT	4	94[c]	92[c]	88[c]	82[c]	77[c]

[a] Digested at 49°C in 17% NaOH, 17% NaOH + 0.2% sodium dodecyl sulfate (SDS), or 17% NaOH + 0.2% Aerosol OT (AOT).

[b] All samples dipped in conventional browning inhibitor solution for 5 min after digestion.

[c-d] Mean of 3 replicates; means within columns, followed by different superscripts, are significantly different at $P < 0.05$ by the Bonferroni LSD test.

greatly extend storage life of the tubers over that without digestion. For example, with digestion treatment, abrasion peeled Russet potatoes showed little change in L-value (−1.6) or a-value (+0.5) following 8 days at 4°C. In contrast, the undigested potatoes showed a large decrease in L (−3.1) and increase in a (+2.4) within 3 days; by day 8, the values were −7.1 and 4.2, respectively.

In further experiments, potatoes peeled with high pressure steam responded well to lye digestion followed by immersion in browning inhibitor solutions (Table 2). In these experiments, tubers previously stored at 20°C or 4°C were digested with 17% NaOH for 4 min at 49°C, a condition that resulted in ready removal of digested tissue without excessive losses. Plugs from digested tubers were treated either with the conventional browning inhibitor formulation or with an experimental formulation, containing ascorbic acid-2-phosphates, that gave favorable results with potatoes in a previous study (Sapers and Miller, 1992). Without lye digestion, Russet and round-white plugs, treated with the conventional inhibitor, were unacceptable between days 3 and 6 at 4°C. Such results are typical for pre-peeled potatoes treated with commercial ascorbic acid-based browning inhibitor formulations (Langdon, 1987; Duxbury, 1987, 1988). Lye digestion extended storage life of both Russet and round-white potatoes to 13–15 days at 4°C with both conventional and experimental browning inhibitor formulations. Tuber storage temperature had no effect on response to digestion. Effectiveness of the lye digestion treatment could be seen by visual comparison of tubers after 14 days at 4°C (Fig. 1). The untreated control was black, and the control treated with conventional ascorbic acid formulation turned brown, while the tuber with a lye digestion surface treatment prior to browning inhibitor application remained white.

The addition of Tween 80 (or Triton X-100; data not shown) to the lye digestion solution did not further improve product stability. This was based on the absence of significant differences among digestion treatments in percent inhibition values on days 13 and 15. Detergents had been added with the expectation that they might solubilize and remove polyphenol oxidase (PPO), physically bound to cell membranes in damaged tissues at the peeled surface, during digestion, thereby decreasing the tendency to brown. Detergents are often used to extract membrane-bound PPO from plant tissues in assay and purification protocols (Mayer and Harel, 1979; Vamos-Vigyazo, 1981).

With both steam and lye peeling, an unstable layer of cooked tissue was produced at the surface of the peeled tuber. Our results demonstrated that the lye digestion treatment developed by Harrington (1957) was highly effective in removing this layer and producing a new surface that responded well to treatment with browning inhibitors. Abrasion-peeled potatoes also have a severely disrupted surface that undergoes rapid browning during storage. However, because of the absence of a cooked layer, it was not evident whether abrasion-peeled potatoes would respond to lye digestion. Percent inhibition data for abrasion-peeled Russet tubers indicated that the undigested control, treated with conventional browning inhibitor formulation, was unacceptable by day 11 (Table 3). Digestion with 17% NaOH extended the storage life of these potatoes to 15 days or longer. Increasing the digestion time had no further effect on shelf-life, based on the absence of significant differences in percent inhibition values between digestion treatments applied for 4 vs 6 min. Similarly, adding anionic detergents to the digestion solution had no effect on treatment effectiveness.

Results clearly showed that the lye digestion treatment was applicable to abrasion-peeled as well as to lye- and high pressure steam-peeled potatoes. In both cases, the hot NaOH solution likely penetrated disrupted layers of cells at the peeled surface, digesting the middle lamellae surrounding parenchyma cells, so that this tissue could be separated from underlying undamaged tissue. The 13–15 day shelf-life that we obtained substantially exceeded that from conventional treatments and avoided the cost and inconvenience of using modified atmospheres (O'Beirne and Ballantyne, 1987) or vacuum packaging (Langdon, 1987) or of packing and shipping pre-peeled potatoes in pails under a cover solution containing citric and sorbic acid (Santerre et al. 1991). Such advantages must be considered with the reduced yield of product and accompanying increase in volume of waste requiring treatment, an additional cost. The presence of NaOH in the waste stream also would add to the cost of waste treatment. The use of lye digestion in conjunction with conventional browning inhibitors may be a viable alternative to sulfiting of pre-peeled potatoes.

REFERENCES

Anonymous. 1990a. Sulfiting agents; revocation of GRAS status for use on "fresh" potatoes served or sold unpackaged and unlabeled to consumers. Fed. Register 55(51): 9826.

Anonymous. 1990b. Court overturns sulfite ban on fresh potatoes. Food Chemical News Aug. 6: 60.

Duxbury, D.D. 1987. Preservative blend extends storage life of fresh potatoes. Food Process. 48(5): 84.

Duxbury, D.D. 1988. Stabilizer blend extends shelf life of fresh fruit, vegetables. Food Process. 49(9): 98.

Feinberg, B., Olson, R.L., and Mullins, W.R. 1987. Prepeeled potatoes. In *Potato Processing*, Fourth ed., W.F. Talburt and O. Smith, (Ed.), p. 697. AVI-Van Nostrand Reinhold, New York.

Harrington, W.O. 1957. Removing cooked tissue from peeled potatoes. U.S. patent 2,797,165.

Harrington, W.O., Mayer, P.C., Olson, R.L., Mullins, W.R., and Potter, A.L., Jr. 1956. Observations on pre-peeling of potatoes. Food Technol. 10: 347.

Langdon, T.T. 1987. Preventing of browning in fresh prepared potatoes without the use of sulfiting agents. Food Technol. 41(5): 64.

Mayer, A.M. and Harel, E. 1979. Polyphenol oxidases in plants. Phytochemistry. 18: 193.

Miller, R.G., Jr. 1981. In *Simultaneous Statistical Inference*, p. 67. Springer-Verlag, New York.

O'Beirne, D. and Ballantyne, A. 1987. Some effects of modified-atmosphere packaging and vacuum packaging in combination with antioxidants on quality and storage life of chilled potato strips. Int. J. Food Sci. Technol. 22: 515.

Santerre, C.R., Leach, T.F., and Cash, J.N. 1991. Bisulfite alternatives in processing abrasion-peeled Russet Burbank potatoes. J. Food Sci. 56: 257.

Sapers, G.M., Douglas, F.W., Jr., Bilyk, A., Hsu, A.-F., Dower, H.W., Garzarella, L., and Kozempel, M. 1989. Enzymatic browning in Atlantic potatoes and related cultivars. J. Food Sci. 54: 362.

Sapers, G.M. and Miller, R.L. 1992. Enzymatic browning control in potato with ascorbic acid-2-phosphates. J. Food Sci. 57: 1132.

Smith, T.J., and Huxsoll, C.C. 1989. Peeling potatoes for processing. In *Potato Processing*, Fourth ed., W.F. Talburt and O. Smith, (Ed.), p. 333. AVI-Van Nostrand Reinhold, New York.

Taylor, S.L., Higley, N.A., and Bush, R.K. 1986. Sulfites in foods: uses, analytical methods, residues, fate, exposure assessment, metabolism, toxicity, and hypersensitivity. Adv. Food Res. 30: 1.

Vamos-Vigyazo, L. 1981. Polyphenol oxidase and peroxidase in fruits and vegetables. CRC Crit Rev. Food Sci. Nutr. 15: 49.

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